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ADAPTING THE FLOW-DIVERSION VALVE AND HOMOGENIZER TO PERMIT AUTOMATED CLEANING-IN-PLACE OF MILK PROCESSING LINES

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CONTENTS

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ADAPTING THE FLOW-DIVERSION VALVE AND HOMOGENIZER TO PERMIT AUTOMATED CLEANING-IN-PLACE OF MILK PROCESSING LINES

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SUMMARY

Engineers of the Transportation and Facilities Research Division's field office at Columbia, Mo., in cooperation with the Department of Food Science and Nutrition, Missouri Agricultural Experiment Station, have modified the control system used to process fluid milk, thereby permitting automated cleaning-in-place of all milk processing line equipment. The modifications, which consist mainly of adapting the wiring of the homogenizer and of the newly designed flow-diversion valve, were impossible to make until the new valve was designed. The modifications also provide for a programed cam timer to control the operation of the homogenizer during cleaned-in-place cleaning and a bypass valve to allow the cleaning solution to flow unrestricted around the homogenizer during the cleaning cycle so that maximum velocity of cleaning solutions is maintained.

The processing system has been designed to incorporate safety features that equal or exceed those required by the U.S. Public Health Service.

Total labor and miscellaneous ownership and operating expenses of the new system are $507.93 per year compared with $797.41 for the system previously used in the University of Missouri Dairy Plant. All of the savings are in labor costs.

INTRODUCTION

Automated cleaned-in-place (CIP) cleaning of the processing lines and most of the equipment used in processing grade A fluid milk has reduced labor requirements in dairy processing plants. Also, the incidence of equipment damage has been reduced by eliminating much of the work of disassembling, washing, and reassembly. The cleaning of most items of equipment has been automated for operation from a control panel. However, two items of equipment that required disassembling or partial disassembling for cleaning were the flow-diversion valve and the homogenizer. The homogenizer could be removed from the processing line and cleaned as a separate unit in a CIP system.

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A new flow-diversion valve designed to be CIP cleaned has recently been approved by the United States Public Health Service (USPHS).2/

This approval means that although the flow-diversion valve can now be cleaned in the CIP system, the homogenizer must still be manually removed from the processing line for cleaning. Manual removal is undesirable because of the labor cost of cleaning the homogenizer and also because the system would still be incompletely automated.

Engineers of the Transportation and Facilities Research Division at Columbia, Mo., in cooperation with the Missouri Agricultural Experiment Station revised the electrical wiring of the flow-diversion valve assembly, making it possible to use the homogenizer as a timing pump. These wiring changes, impossible to make until the new valve was available, now permit CIP cleaning of all milk processing lines and equipment as a complete unit--from raw milk tanks, through the pasteurizer, to the pasteurized milk storage tanks and packaging equipment. The modified system has been installed at the University of Missouri Dairy Plant at Columbia and is being tested under production conditions. The system has the approval of the Missouri Division of Health to be operated at the University of Missouri Dairy Plant.

DESCRIPTION OF COMPONENTS

The components of the system consist of the flow-diversion valve assembly and two control panels. The flow-diversion valve assembly includes a divert valve and a leak-detector valve. The main controls for the flow-diversion valve assembly are in a control panel (fig. 1) that is wired to the pasteurizer temperature controller and recorder. The control panel contains two electrically operated solenoid valves, a time delay relay, a recycle cam timer, and a terminal board.

An auxiliary panel (fig. 2) houses supplemental control equipment needed to permit the homogenizer to operate during the cleaning cycle and the wash-water to flow unrestricted past the homogenizer during the cleaning cycle. The panel contains an electrical time delay relay, a pneumatic time delay relay, an electrically operated solenoid valve, a single-cam or pulsing cam timer, and a terminal board.

The flow-diversion valve control panel contains two switches, a manual divert switch and a three-position selector switch. The selector switch is used to choose one of the three following positions: "inspect" - for inspection; "product" - for normal pasteurization; and "clean" - for cleaning. The manual divert switch moves the divert and leak-detector valves to the divert-flow position from the forward-flow position when the selector switch is in the "product" setting without reducing the temperature of the product or causing an air failure.

2/ Carson, Robert B. Flow-Diversion Valve - Model No. 262D121, Tri-Clover Division, Ladish Co., Kenosha, Wisconsin, U.S. Pub. Health Serv. Off. Memo. M-b94, 3 pp. August 4, 1966. /Mimeographed./

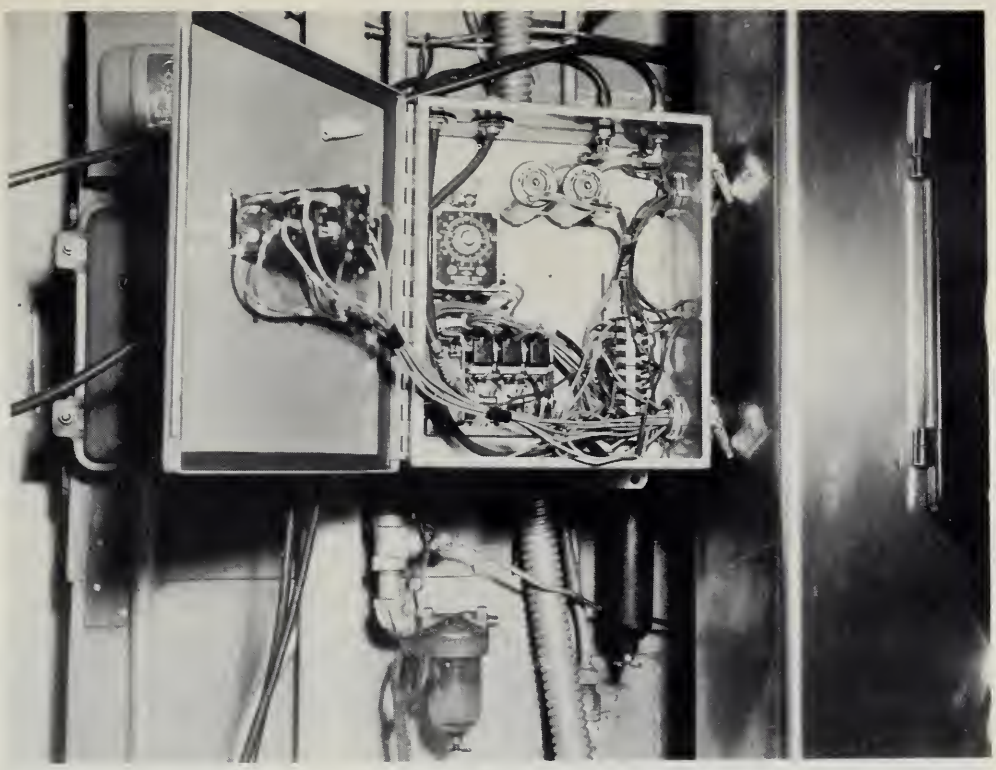

Figure 1.--Flow-diversion valve assembly control panel.

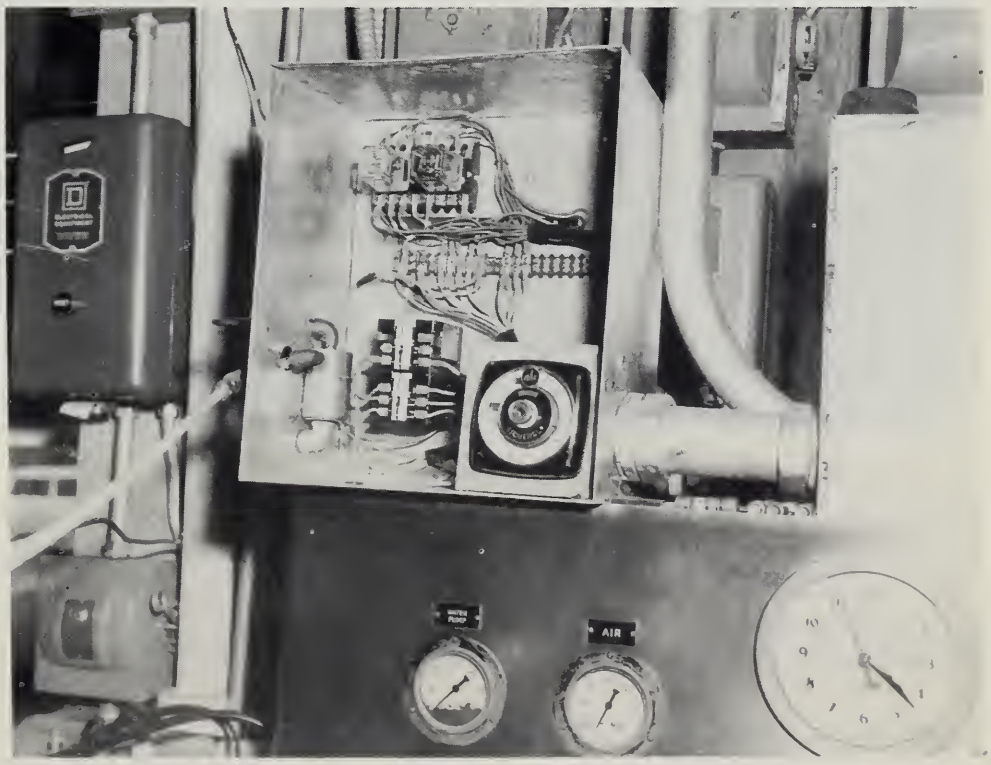

Figure 2.--Flow-diversion (bypass) valve assembly auxiliary control panel.

OPERATION OF THE SYSTEM

The flow-diversion valve is wired so that the timing pump (homogenizer) cannot run when the selector switch is in either the "clean" or "inspect" setting. This feature eliminates the possibility of unpasteurized milk passing through the flow-diversion valve should the selector switch accidentally be turned to the "clean" or "inspect" position during the startup operation. The centrifugal feed pump is wired to operate only when the homogenizer is operating.

The original wiring diagram, as listed by the USPHS for the flow-diversion valve, was revised to permit the timing pump (homogenizer) to run during the programed cleaning of the processing line. The timing pump is a positive metering device that forces the milk through the pasteurizing system at a predetermined rate. A bypass valve (fig. 3) was installed to permit the washwater to flow unrestricted around the homogenizer during cleaning. Regulatory

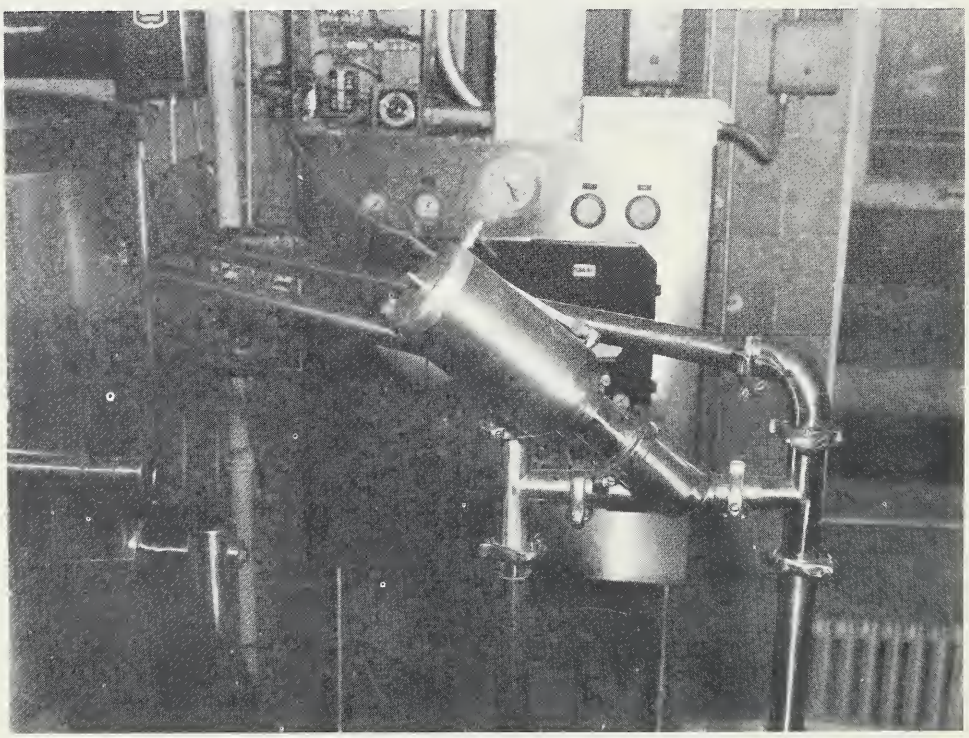

Figure 3.--Homogenizer bypass valve.

agencies recommend that the minimum velocity of washwater be 5 feet per second to insure adequate cleaning. The velocity of milk during processing with the bypass valve closed ranges from approximately 0.5 to 2 feet per second, depending on the design of the system.

The function of each component will be explained in the following description of the flow-diversion valve selector switch settings. A detailed explanation of the wiring diagrams, which show relationships between different components of the system, is given in the Appendix.

Processing

When the processing system is not operating, the selector switch is set in the "product" position. During startup and processing, the selector switch remains in the "product" position and the homogenizer and centrifugal feed pumps are started by manually energizing their control switches. The centrifugal feed pump will not start until the homogenizer starts. With the selector switch in the "product" position, all the pasteurization controls are operative.

During startup, the unpasteurized milk flows through the holding tube into the divert-flow valve, which directs the milk back to the constant level tank as shown in figure 4A. When the milk in the holding tube reaches the legal pasteurization temperature, the temperature controller closes an electrical circuit, resulting in movement of the divert-flow valve to the forward-flow position. The leak-detector valve is delayed (delay adjustable from 0 to 15 seconds) in its movement to the forward-flow position by a time delay relay. This time delay permits all unpasteurized milk that may have accidentally leaked past the divert-flow valve to be flushed out of the leak-detector chamber before the leak-detector valve assumes the forward-flow position. The leak-detector valve is shown in its diverted-flow and forward-flow positions in figure 4B and C.

When the temperature in the holding tube drops below pasteurization level, the flow-diversion valve instantly assumes the divert-flow position. When the pasteurization temperature is again reached, the divert and leak-detector valves will assume the forward-flow position as described above.

Inspecting

The selector switch is moved to the "inspect" setting to check or inspect the valve seats to determine if a satisfactory job of cleaning is being done. In the "inspect" setting, all components are inoperative; the equipment can be dismantled and checked with complete safety since it is not possible to activate accidentally any portion of the system.

Cleaning

To start the cleaning operation at the completion of the processing cycle, the selector switch is moved to the "clean" setting, actuating a series of control devices that (1) starts a cam timer (recycle type); (2) starts a time delay relay (adjustable from 0 to 120 seconds); (3) stops the timing pump and the centrifugal feed pump; and (4) disconnects circuitry that renders all pasteurization controls inoperative (the temperature recorder remains functional).

The flow-diversion valve is set in different positions for cleaning by the recycle cam timer. The initial flow-diversion valve setting, divert-flow position, is shown in figure 4A. In this position, the cleaning solution flows from the holding tube into the divert valve, out through the divert port,

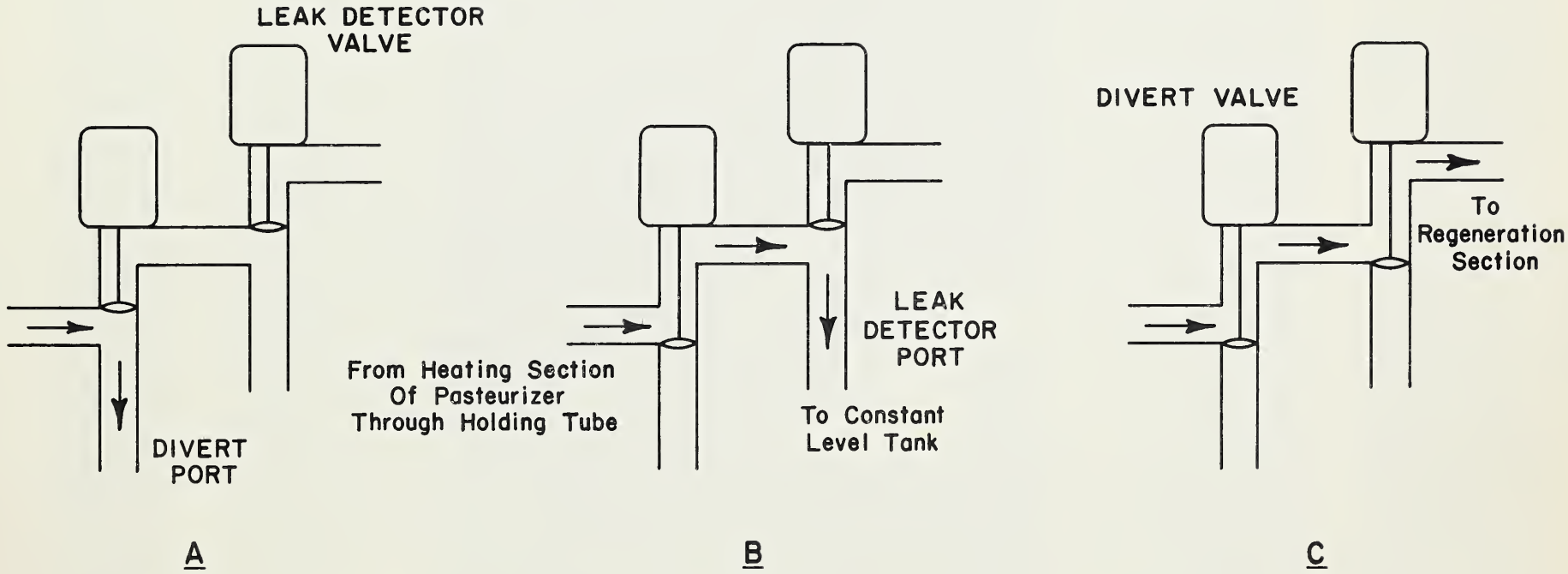

Figure 4.--Flow-diversion valve assembly: A, Diverted-flow position; B, leak-detector-flow position; C, forward-flow position.

and returns to the constant level tank. This flow of cleaning solution cleans the line connecting the divert valve and the constant level tank. The duration of flow through the divert-flow port is controlled by adjusting a cam on the recycle cam timer.

An electrically operated solenoid is energized by one of the rotating cams on the recycle cam timer. In the energized position, the solenoid permits air under pressure to enter the actuator, which moves the divert valve stem to the forward-flow position. The flow of washwater is directed through the divert valve, into the leak-detector valve, out the leak-detector port, and back to the constant level tank (fig. 4B). This movement of washwater cleans the divert valve, the leak-detector port, and the line connecting the leak-detector port and constant level tank. The duration of the flow through the line is controlled by adjusting a cam on the recycle cam timer.

An electrically operated solenoid that controls the air supply to the leak-detector valve is energized by one of the rotating cams on the recycle cam timer. The energizing of this solenoid permits air under pressure to flow into the actuator on the leak-detector valve, moving the valve stem to the forward-flow position, as shown in figure 4C. The forward-flow position of the flow-diversion valve assembly is maintained for the remainder of the cycle to permit cleaning of the regenerative (pasteurized side) and cooling sections of the pasteurizer and the pasteurized milk lines leading to the pasteurized milk storage tanks and packaging equipment. At the completion of the cycle, which lasts approximately 60 seconds, the divert and leak-detector valves are returned to their respective divert-flow positions. The cycle as mentioned above is repeated until the selector switch is moved from the "clean" setting.

A time delay relay controls the homogenizer circuit and bypass valve. After the time delay relay has closed a set of contact points in the homogenizer circuit, the homogenizer may be started by the cleaning cycle programed cam timer in the main control panel. The energizing of the homogenizer circuit by the programed cam timer switches control of the homogenizer from its process control station to the programed cam timer for cleaning. When the homogenizer cleaning circuit is deenergized, the control of the homogenizer is switched back to its normal process control station.

The homogenizer is cleaned by running it periodically during the cleaning cycle (fig. 5B). When run during the cleaning cycle, the homogenizer pulls in cleaning solution from the upstream side of the bypass valve and forces the cleaning solution out the downstream side. This operation also cleans the lines leading to and from the homogenizer. The flow-diversion valve assembly is in the divert-flow position when the homogenizer (timing pump) is operated during this cycle. During processing, the bypass valve remains closed (fig. 5A).

The time delay relay energizes a solenoid that allows air to flow into the actuator of the homogenizer bypass valve, causing the valve to open. The homogenizer bypass valve permits the cleaning solution to flow unrestricted around the homogenizer, yet the homogenizer may be run and will receive adequate cleaning solution. The time delay relay also energizes a single-cam cam timer that breaks the circuit to the solenoid valve, causing the homogenizer bypass valve to be pulsed once each 30 seconds during the cleaning cycle.

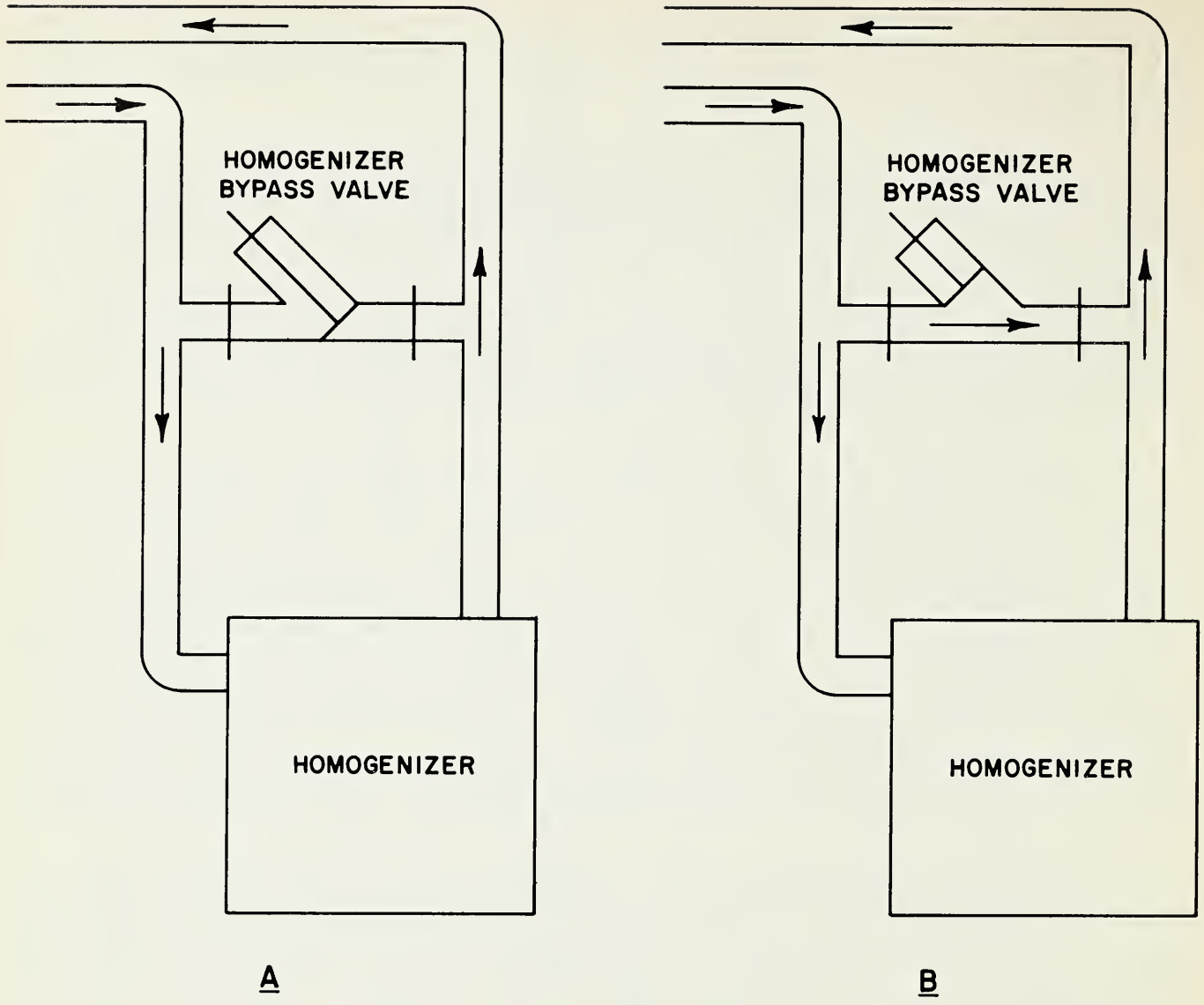

Figure 5.--Homogenizer bypass valve. A, Bypass valve closed (the direction of arrows indicates flow of milk during the processing operation); B, bypass valve open (the direction of arrows indicates flow of cleaning solution during the cleaning cycle).

SIGNIFICANT FEATURES OF THE SYSTEM

The fluid milk processing and cleaning system described in this report has the following built-in operating and safety features that meet or exceed those required by the USPHS:

1. Programed cam timers control CIP cleaning of the processing line.

2. The homogenizer can be started by the programed cam timer during the wash cycle only when the selector switch is in the "clean" setting.

3. The time delay relay provides the system with a timed delay when switching from the "product" to the "clean" cycle. The homogenizer bypass valve is delayed in opening. This delays the centrifugal feed pump from forcing a surge of milk through the holding tube in less than the legal pasteurization time should the selector switch accidentally be turned to the "clean" cycle during processing. The delayed closing of contact points on a control relay prevents the homogenizer from being started by the cam timer before the system is ready for cleaning.

4. The homogenizer bypass valve, spring loaded and normally closed, is positioned so the pressure of the milk from the centrifugal feed pump tends to keep the valve closed.

5. The homogenizer bypass valve is self-cleaning because it is automatically pulsed during the cleaning cycle.

6. The centrifugal feed pump, which feeds the homogenizer, will not operate unless the homogenizer is operating.

7. Components of the system, electrical and pneumatic, are designed so that malfunction or failure of the system will in no way affect the quality of the milk.

COST COMPARISON

A detailed breakdown of the costs of ownership and operation of equipment is given in table 1. The analysis compares the cost of system A, used by the University of Missouri Dairy Plant before the plant was automated, and system B, used after automation. The equipment performs the same functions in both systems.

System A included a COP (cleaned-out-of-place) flow-diversion valve and a variable-speed positive pump used as the timing pump. System B included a CIP flow-diversion valve, a centrifugal feed pump (used to pump milk to the homogenizer), a bypass valve, and an auxiliary control panel. The homogenizer was not considered in the cost analysis, because it was part of both systems.

Annual equipment ownership and operating costs were $504.11 for system A and $507.93 for system B. The ownership and operating costs for system B are only $3.82 higher than for system A.

The labor required to disassemble and reassemble the flow-diversion valve and the positive pump used in system A is 83.8 man-hours per year. The prevailing wage rate in the area for this type of work is $3.50 per hour. Thus, system A has an annual labor cost of $293.30. System B is completely automated and involves no labor expense.

The total annual labor and equipment costs were $797.41 for system A and $507.93 for system B. The net annual savings is $289.48.

TABLE 1.--Ownership and operating costs of specific automated and nonautomated dairy plant equipment

Equipment	Initial cost (installed) 1/	Ownership costs				Operating costs			Total cost
		Depreciation 2/	Interest 3/	Taxes and insurance 4/	Total	Power 5/	Maintenance 6/	Total	
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
System A (nonautomated):									
COP flow-diversion valve	890.68	74.22	28.95	35.62	138.79	--	37.14	37.14	175.93
Variable speed positive pump	1,490.40	124.20	48.44	59.62	232.26	36.17	59.75	95.92	328.18
Total	2,381.08	198.42	77.39	95.24	371.05	36.17	96.89	133.06	504.11
System B (automated):									
CIP flow-diversion valve	1,397.25	116.43	45.41	55.89	217.73	--	55.89	55.89	273.62
Centrifugal feed pump	355.35	29.61	11.55	14.21	55.37	--	14.21	50.38	105.75
Auxiliary control panel	230.00	19.17	7.48	9.20	35.85	--	6.90	6.90	42.75
Sight glass	127.65	10.64	4.15	5.11	19.90	--	5.11	5.11	25.01
Bypass valve	310.50	25.87	10.09	12.42	48.38	--	12.42	12.42	60.80
Total	2,420.75	201.72	78.68	96.83	377.23	36.17	94.53	130.70	507.93

1/ Initial cost plus 15 percent for freight and installation.

2/ Depreciation based on Internal Revenue Service Publication 456, 92 pp. August 1964.

3/ Interest computed using the formula $E=\frac{R(N+1)}{2N}$ where E = average interest rate per year, R = interest rate required for investment (6 percent), and N = life expectancy of the item.

4/ Taxes and insurance based on 4 percent of initial investment.

5/ Power based on 70-percent efficiency and use of a 1-hp. electric motor. Rate calculated at 2 cents per kw.-hr.

6/ Average maintenance for life of equipment is calculated at 4 percent.

APPENDIX

Electrical Controls for Homogenizer Bypass Valve

Several electromechanical components were added to the existing system. The wiring diagrams shown in figures 6, 7 and 8 are supplements to the manufacturer's wiring diagram[3/] and show the components that were placed in an auxiliary control panel (fig. 2) and the processing line.

The components added to the existing system are as follows:

1. Contact block 4 is attached to contact block 3 on the selector switch to provide a set of contact points that are open in the "inspect" and "product" settings and closed in the "clean" setting. Four contact blocks (two contact points per block) are attached to the selector switch, and their contact points are referred to as CP-1 through CP-7 (CP-8 is not used). Contact block 4 (one set of points normally open, NO, and one set of points normally closed, NC,) contains contact point 7 (CP-7), which controls a time delay relay (TR-4), which, in turn, controls several other components.

2. Control relay No. 2 (CR-2) is used in a switching circuit to permit the homogenizer to run during the cleaning operation. CR-2 is energized after a time delay but only when the selector switch is in the "clean" setting.

3. Single-cam cam timer (CT-2), 30-second cycle, is used to pulse the homogenizer bypass valve. The length of the pulsing period is adjustable. The cam should be set to allow the valve stem to move to a partially closed position and then return to the open position. This pulsing permits the valve to be cleaned but does not restrict the flow of cleaning solution through the valve.

4. Bypass valve (fig. 3) and the solenoid valve (SV-3) that operates it permit the cleaning solution to flow unrestricted past the homogenizer during the cleaning cycle.

5. Time delay relay (TR-4) delays the opening of the bypass valve and the energizing of control relay No. 3 (CR-3). CR-3 permits the homogenizer to run during the cleaning cycle. TR-4 delays the opening of the homogenizer bypass valve each time the selector switch is moved to the "clean" setting. The time delay allows the centrifugal feed pump to stop before the cleaning cycle starts.

Electrical Controls for Flow-Diversion Valve Assembly

The flow-diversion valve assembly is wired to prevent the timing pump from running when the selector switch is in either the "clean" or "inspect" setting. (The wiring of the control circuit is given in the manufacturer's wiring diagrams 91D212-1, 91D212-2, and 91D212-3. The three different

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3/ Diagram No. 91D212-3, Ladish Co., Kenosha, Wis.

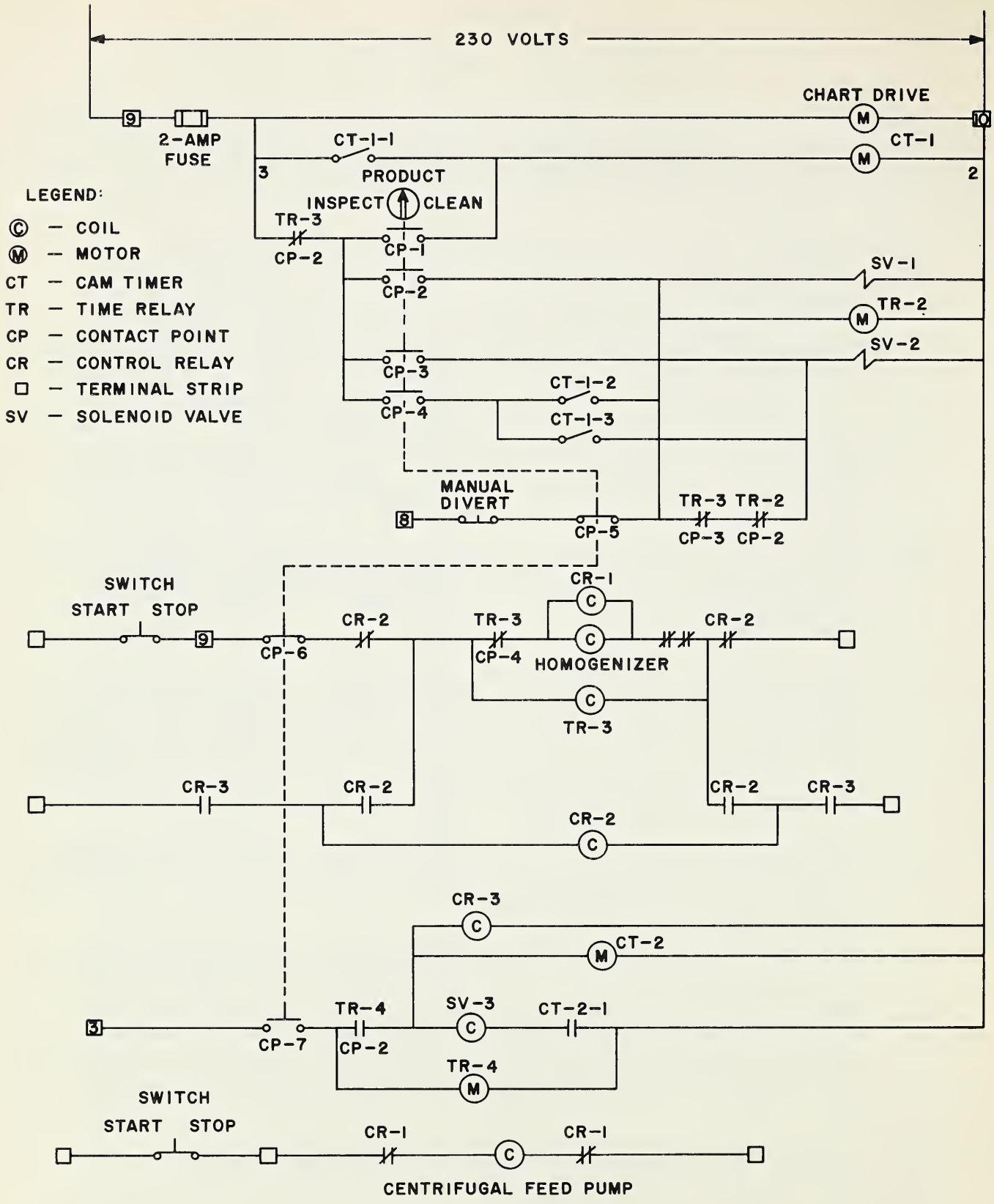

Figure 6.--Wiring diagram for product cycle.

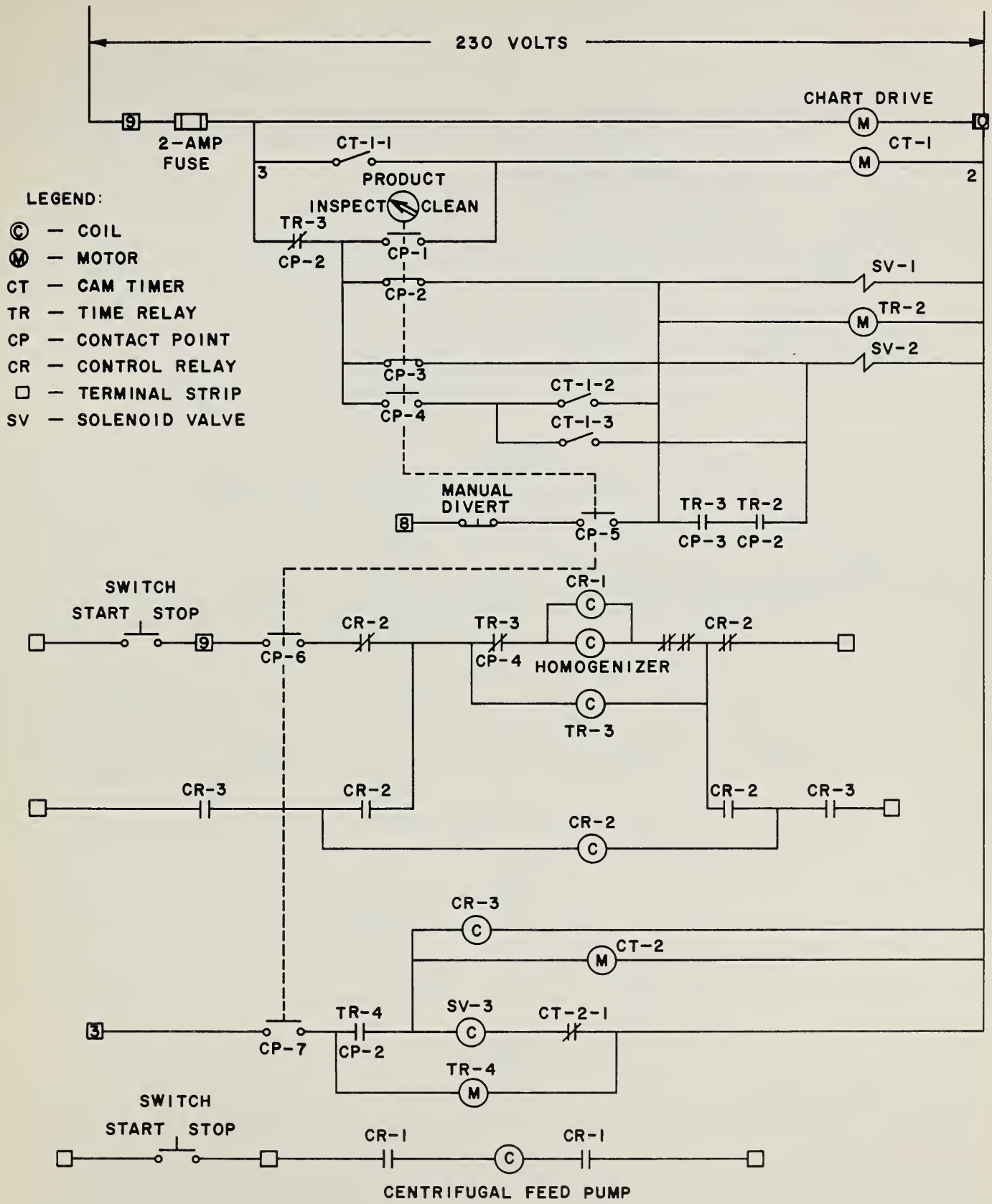

Figure 7.--Wiring diagram for inspect cycle.

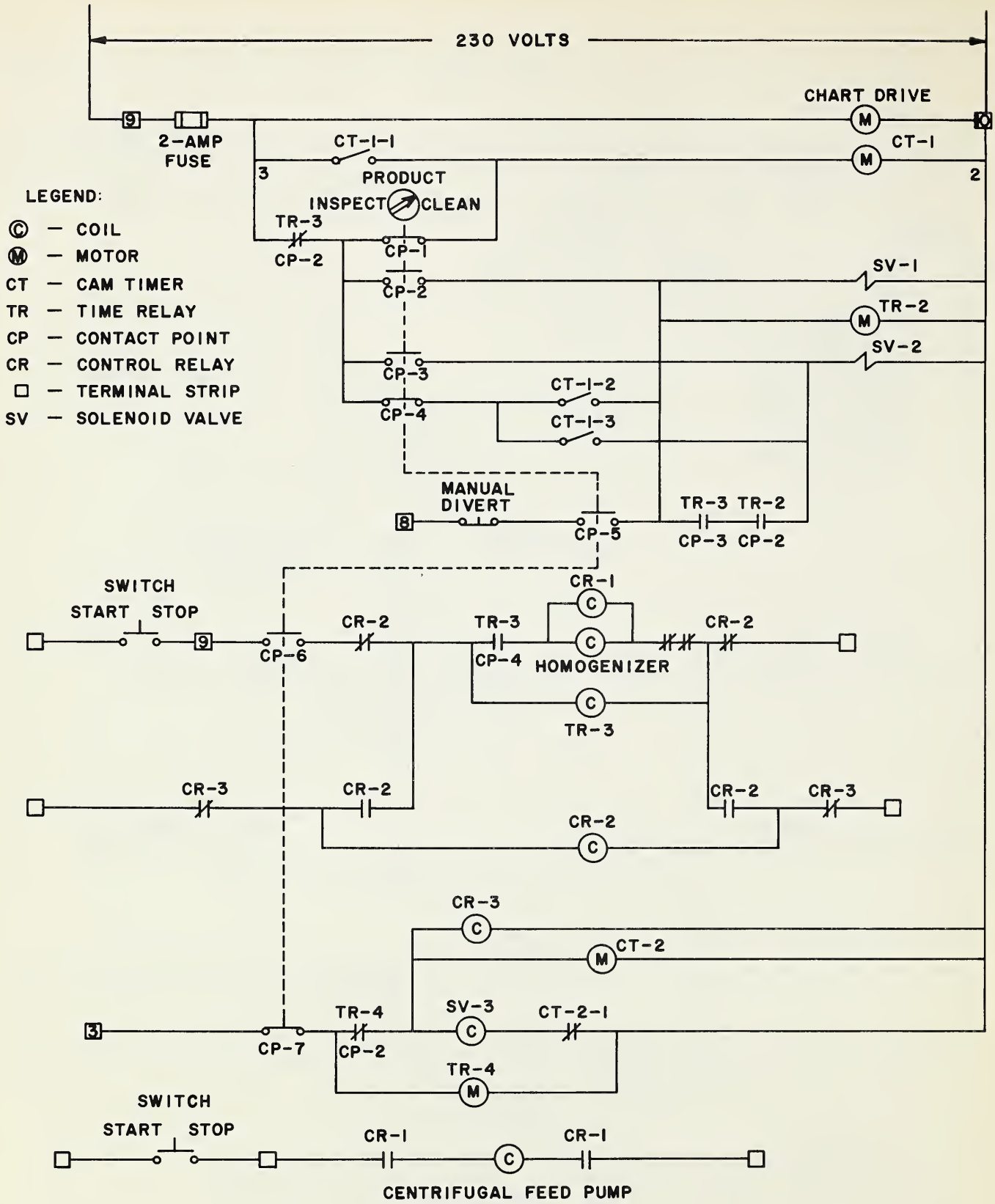

Figure 8.--Wiring diagram for clean cycle.

wiring diagrams are needed because of the different models of temperature controllers and recorders to which the unit may be connected.)

The manufacturer's wiring diagram[4/] must be revised as shown in figures 6, 7 and 8 to permit the timing pump (homogenizer) to run during the programmed cleaning of the processing line and to permit the cleaning solution to bypass the homogenizer during the cleaning cycle.

The function of each electrical component added to the circuit will be explained in the following description of the selector switch settings. Contact points (CP-Nos.) are controlled by the selector switch unless they are identified as contact points on individual components, such as time delay relays (TR-Nos.) and control relays (CR-Nos.).

Prior to startup, the selector switch is in the "product" setting and the positions of the electrical components are as follows: CP-2 of TR-3 and CP-5 and CP-6 are closed; CP-1, 2, 3, 4, and 7 are open.

The homogenizer is started from its control station. The current passes through CP-6 and CR-2 to energize TR-3. With TR-3 energized, the closing of CP-4 of TR-3 causes the homogenizer to start and the coil on CR-1 to be energized. The closing of CR-1 permits the centrifugal feed pump to be started from its control station. The energizing of TR-3 also causes CP-2 on TR-3 to be opened, which prevents the flow-diversion valve from moving to or remaining in the forward-flow position when the homogenizer is operated during the cleaning cycle.

The closing of CP-3 of TR-3 permits the temperature controller to regulate the flow-diversion valve assembly during the pasteurization cycle. The timing pump (homogenizer) must be running for the flow-diversion valve assembly to be operative. All pasteurization controls must be operative so that pasteurization can occur.

When the milk in the holding tube reaches the legal pasteurization temperature, the temperature controller energizes the pasteurization circuit through CP-5. The coil on SV-1 is energized, permitting air to flow into the actuator on the divert valve, which moves the divert valve to the forward-flow position. At the same time that SV-1 is energized, the motor on TR-2 is started. After a preset time, adjustable from 0 to 15 seconds, CP-2 on TR-2 is closed and SV-2 is energized. This energizing of SV-2 permits air pressure to move the leak-detector valve to the forward-flow position.

During pasteurization the electrical contacts are as follows: CP-2 on TR-3 is open; CP-3 and CP-4 on TR-3 are closed; CP-2 on TR-2 is closed; CP-1 through 4 and CP-7 are open; CP-5 and CP-6 are closed. The circuit positions are shown on figure 6.

If the temperature in the holding tube drops below legal pasteurization temperature, the temperature controller deenergizes the pasteurization circuit through CP-5. SV-1 and SV-2 are deenergized instantly, causing the divert and leak-detector valves to assume the divert (startup) position.

4/ See footnote 3.

The programed cam timers for the processing line cleaning cycle control the complete cleaning of the system.

As shown in figure 4A, B, and C, the divert and leak-detector valves are placed in the three cleaning positions by the recycle cam timer (CT-1). The flow of cleaning solution through the divert-valve port cleans the line connected to the balance tank (fig. 4A). Flow of the cleaning solution through the leak-detector valve permits the leak-detector line to be cleaned (fig. 4B). Forward flow through the divert and leak-detector valves cleans the processing line (fig. 4C).

To start the cleaning cycle during the cleanup operation, the selector switch is moved to the "clean" setting. The positions of the controls are as follows: CP-1, CP-4, and CP-7 are closed; CP-2, CP-3, CP-5, and CP-6 are open. CP-2 on TR-3 is closed (these points are delayed in closing each time the timing pump is stopped). When CP-7 is closed, current starts the motor on TR-4. After a predetermined time, 0 to 120 seconds, CP-2 on TR-4 is closed, which allows the current to energize the coils on CR-3 and SV-3 and start the motor on CT-2.

CR-3 closes the homogenizer control circuit, permitting the homogenizer to be started by the programed cam timer. To start the homogenizer, the programed CIP cam timer energizes CR-2 through CR-3. This energizing breaks the circuit to the normal homogenizer control center. When SV-3 is energized, air flows into the homogenizer bypass valve, causing the valve to open. The current to CT-2 causes the motor to run and rotates the cam, which breaks the SV-3 circuit every 30 seconds. The breaking of the circuit to SV-3 causes the bypass valve to be pulsed. The duration of the pulsing period is determined by the cam setting.

When the homogenizer is started by the programed cam timer during the cleaning cycle, the flow-diversion valve assembly instantly assumes the divert-flow position. The placing of the flow-diversion valve in this position is caused by the opening of CP-2 on TR-3 when TR-3 is energized by the current in the homogenizer circuit. The single-cam cam timer continues to operate; however, the valves will not pulse because no current will flow through CP-4. That part of TR-3 identified as CT-1-2 and CT-1-3 on figure 8 assumes control of the flow-diversion valve as soon as CP-2 on TR-3 is closed after the homogenizer stops. CP-2 on TR-3 is delayed in closing each time the homogenizer is stopped so that the flow-diversion valve cannot assume the forward-flow position before the timing pump stops.

When the selector switch is moved to the "inspect" setting, the flow-diversion valve is moved to the forward-flow position for inspection, and all pasteurization controls are rendered inoperative.

When the selector switch is moved from the "product" setting to "inspect", the following changes occur: CP-2 on TR-3 is closed; CP-1, CP-4, CP-5, CP-6, and CP-7 are open; CP-2 and CP-3 are closed (these two circuits permit the flow-diversion valve to assume the forward-flow position for inspection); CP-3 on TR-3 and CP-2 on TR-2 are open. All controls are inoperative when the selector switch is in the "inspect" setting. The circuitry is shown in figure 8. When the selector switch is turned back to the "product" setting, the circuitry will be that shown in figure 6.

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